Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L. em. Thell.)

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Abstract

Combining ability was analyzed using a half diallel of ten parents in bread wheat (*Triticum aestivum* L. em. Thell.). Combining ability analysis, revealed the importance of both additive as well as non-additive genetic variances for control of various traits. However, the ratio of σ^2gca/ σ^2sca revealed preponderance of non-additive gene actions in almost all the traits. Parents Raj 4063, HD 2851 and WH 789 were the good general combiners, whereas crosses WH 789 x NW 3015, HUW 468 x UP 2614 and HS 448 x Raj 4063 were found to be best specific combiners for grain yield per plant and some of the yield contributing traits. However on the basis of per se performance and significant sca effects for grain yield per plant and some of its important components, hybrids WH 789 x NW 3015; HS 448 x Raj 4063 and K 209 x HD 2851 were considered to be most promising for further exploitation in breeding programmes.

Key words: wheat, general combining ability, specific combining ability

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Introduction

Wheat was one of the first domesticated food crops and for 8000 years has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including rice, maize and potatoes.

It is the leading grain crop of the temperate climates of the world, and is grown on 222 million hectares in the world (FAO, 2011). In India it stands at second position just after rice which contributes nearly one third of total food grain production. At global level, India ranks second largest wheat producing nation with 13.4 per cent global wheat production after China which contributes 17.7 per cent to the world wheat production. The other wheat producing countries are Russian Federation, United States of America and Canada and these five countries together contribute more than half of the global wheat production. To fulfill the increasing food demand of the world population, wheat production and productivity must be increased (USDA, 2012).

The increase in yield potential has always been of fundamental importance in wheat breeding programmes. Genetic analysis of wheat yield improvement had shown that grain yield is determined by component traits, and is a highly complex character (Adams, 1967; Blum, 1988). The analysis showed that genes for yield per se do not exist (Grafius, 1959). Therefore, knowledge about combining ability is important in selecting suitable parents for hybridization, understanding of inheritance of quantitative traits and also in identifying the promising crosses, are of paramount importance in formulating an efficient breeding programme. Keeping in view, present investigation was carried out to obtain more precise estimates of combining ability for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L. em. Thell.).

Materials and methods

The present investigation aimed to gather information on the genetic basis of yield and its contributing traits in ten diverse genotypes of bread wheat (*Triticum aestivum* L. em. Thell.) *viz.* HD 2881, HS 448, WH 789, HUW 468, UP 2614, NW 3015, PBW 520, K 209, HD 2851 and Raj 4063 selected from the germplasm maintained at Agricultural Research Station, Durgapura, Jaipur in AICW&BI Project of ICAR, on the basis of a broad range of genetic diversity for major yield components. These selected genotypes were planted at Agricultural Research Station, Durgapura, Jaipur, for hybridization in diallel fashion excluding reciprocals. The experiment was laid out in a randomized block design with three replications. The experiment plot comprised two rows each of 4 meter length. Row to row and plant to plant spacing was maintained at 30 cm and 10 cm. Recommended uniform agronomical practices were followed for raising the crop in all the three environments. Observations were recorded on twenty randomly selected competitive plants of each parent and F_1's in every replication for following traits *viz*, days to heading, days to

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maturity, plant height (cm), tillers per plant, flag leaf area (cm^2), peduncle length (cm), spike length (cm), number of spikelets per spike, number of grains per spike, grain yield per spike (g), 1000-grain weight (g), biological yield per plant (g), harvest index (%) and grain yield per plant (g). In case of maturity traits (days to heading & days to maturity), the data was recorded on the whole plot basis. The mean of each plot used for statistical analysis. The data were first subjected to the usual analysis followed for a randomized block design for individual environment as suggested by Panse and Sukhatme, 1985. The combining ability analysis was done following Griffing's method 2, Model I (1956).

Results and discussion

Significant differences were observed among the treatments (parents and their F_1s) revealing existence of variability for all the traits. Analysis of variance for combining ability (Table 1) revealed that mean squares due to GCA as well as SCA were significant for all the traits, indicating the importance of both additive and non-additive gene effects in the inheritance of characters. However, the ratio of σ^2gca/ σ^2sca was recorded below unity showed preponderance of non-additive type of gene actions for all the characters. Similar results were earlier reported by Menon and Sharma (1994), Kathiria and Sharma (1996), Esmail (2002), and Gothwal (2006).

Table 1. ANOVA for combining ability for various characters in F_1 in wheat

Character	Source of variation			
	GCA (df = 9)	SCA (df = 45)	Error (df =108)	GCA/SCA variance
Days to heading	15.82**	2.82**	0.94	0.66
Days to maturity	10.04**	1.84**	0.60	0.64
Plant height	44.04**	11.60**	1.67	0.36
Tillers per plant	3.13**	0.49**	0.03	0.56
Flag leaf area	28.52**	24.22**	0.99	0.10
Peduncle length	15.52**	6.74**	0.89	0.21
Spike length	2.26**	1.58**	0.17	0.12
Number of spikelets $spike^{-1}$	2.15**	1.79**	0.36	0.10
Number of grains $spike^{-1}$	82.62**	63.88**	1.12	0.11
Grain yield $spike^{-1}$	0.31**	0.12**	0.01	0.22
1000- grain weight	29.11**	10.05**	0.58	0.25
Biological yield $plant^{-1}$	146.21**	50.94**	0.68	0.24
Harvest index	23.01**	7.07**	1.41	0.32
Grain yield per plant	26.71**	6.27**	0.10	0.36

**, ** Significant at 5 per cent & 1 per cent levels, respectively.*

The estimates of GCA effects for grain yield per plant & other contributing traits are presented in Table 2. The parent classified as good, average and poor combiners on the basis of estimates of combining ability effects for various characters. It was observed that none of the parents was good general combiner for all the characters.

However, the parent Raj 4063 was found to be good general combiners for grain yield per plant and most of the yield attributing traits viz., days to heading, number of tillers per plant, flag leaf area per plant, number of grains per plant, grain yield per spike, 1000- grain wt., biological yield per plant and harvest index; HD 2851 for days to maturity, plant height and tillers per plant, flag leaf area per plant, 1000- grain wt., biological yield per plant; HUW 468 for grain yield per plant, number of grains per spike, grain yield per spike, spike length, biological yield per plant and grain yield per spike; WH 789 for 1000- grain wt., biological yield per plant and grain yield per plant; HD2881 for grain yield per plant, biological yield per plant, 1000- grain wt. and grain yield per spike were found to be good general combiners. In general it is evident from the table that the parents which were good general combiners for grain yield per plant were also good general combiners for some of its yield contributing traits like days to heading, days to maturity, plant height, tillers per plant, flag leaf area, spike length, number of grains per spike, 1000-grain weight and biological yield per plant. From the result it is observed that the use of parent HD 2851, HUW 468 and Raj 4063 in future breeding programme would be more useful for augmenting genes for high grain yield in bread wheat, as they are found to be good general combiners for grain yield per plant and some of the important yield components. It was interesting to note that parent Raj 4063 exhibited superior performance for grain yield per plant.

Table 2. Estimates of GCA effects for grain yield per plant & other contributing traits in normal environments

Parent	Days to heading	Days to maturity	Plant height	Tiller per plant	Flag leaf area	Spike length
HD 2881	1.02 ***	1.87 ***	2.07**	0.09	-0.60*	0.02
HS 448	0.19	-1.35 ***	1.25**	-0.34**	-1.19**	0.03
WH 789	-1.01 ***	-0.43 *	-1.62**	0.23**	0.28	-0.63**
HUW 468	0.38	-0.41	1.39**	-0.30**	0.87**	0.72**
UP 2614	1.44 ***	0.29	-0.70*	-0.64**	1.03**	0.24*
NW 3015	-0.03	0.29	1.47**	-0.01	-0.34	-0.13
PBW 520	0.69 *	-0.02	0.03	-0.27**	-3.20**	-0.56**
K 209	0.86 **	0.34	1.23**	-0.33**	-0.56*	-0.24*
HD 2851	-1.56 ***	-1.13 ***	-4.20**	0.44**	2.14**	-0.03
Raj 4063	-1.98 ***	0.54 *	-0.92**	1.14**	1.58**	0.58**
SE (gi)+	0.265	0.213	0.354	0.048	0.273	0.114
SE (gi-gj)+	0.395	0.317	0.527	0.071	0.408	0.169

Parent	Number of grains per spike	Grain yield per spike	1000- grain wt.	Biological yield per plant	Harvest index	Grain yield per plant
HD 2881	-0.85**	0.07**	2.07**	1.54**	-1.15**	0.30**
HS 448	-1.76**	-0.07**	-0.3	-1.61**	-1.61**	-1.02**
WH 789	-0.91**	0.01	1.36**	2.23**	-1.47**	0.31**
HUW 468	5.74**	0.24**	0.36	0.69**	-0.04	0.26**
UP 2614	-0.1	-0.11**	-1.89**	3.45**	-0.12	-1.36**
NW 3015	0.38	-0.04	-1.02**	0.99**	-0.03	0.29**
PBW 520	-3.22**	-0.19**	-1.26**	-4.10**	-0.05	-1.47**
K 209	-1.66**	-0.17**	-2.17**	-4.05**	0.75*	-1.21**
HD 2851	-0.84**	-0.04	0.89**	0.48*	0.5	0.27**
Raj 4063	3.22**	0.29**	1.95**	7.28**	3.22**	3.63**
SE (gi)+	0.29	0.019	0.209	0.225	0.325	0.087
SE (gi-gj)+	0.432	0.029	0.311	0.335	0.485	0.130

Best parent having desirable GCA effects for grain yield per plant are presented in Table 2. It was revealed that the GCA effect and per se performance were positively correlated in most of the best parents. Though, such pattern was not prevailed in all the cases. Perusal of Table 2 revealed that the parents, who showed desirable, GCA effects for grain yield per plant, also exhibited desirable GCA effects for one or more yield attributing traits. The parents Raj 4063, WH 789 and HUW 468 emerged as good general combiners for grain yield and some associated traits. Earlier, Kathiria and Sharma (1996), Rajora and Maheshwari (1996), Singh (1998), Rajora (1999), Punia (2003), Joshi *et al.* (2003a), Desai *et al.* (2005) and Singh and Chaudhary (2008) provided similar information on combining ability in wheat. In all such cases where GCA effect was more pronounced for particular trait indicating preponderance of additive gene action, so these genotypes should be involved in crosses to improve the specific trait in future breeding programme.

In self-pollinated crops like wheat, SCA effects are not much important as they are mostly related to non-additive gene effects excepting those arising from complementary gene action or linkage effects they can not be fixed in the pure line or the end product inbred line. Jinks and Jones (1958) emphasized that the superiority of the hybrids might not indicate their ability to yield transgressive segregants, rather SCA would provide satisfactory criteria. However, if a cross combination exhibiting high SCA as well as high *per se* performance having at least one parent as good general combiner for a specific trait, it is expected to throw desirable transgressive segregants in later generations (Kathiria and Sharma, 1996). An overall appraisal of specific combining ability effects revealed that some crosses had significant SCA effects for a few specific characters across the environments with varied magnitudes. For e.g., HS 448 x WH 789 for flag leaf area, number of grains/ spike, grain yield/ plant and biological yield per plant; WH 789 x PBW 520 for flag leaf area, grain yield per plant and biological yield x plant; WH 789 x K 209 for number of grains per spike and grain yield per spike; HUW 468 x UP 2614 for number of spikelets per spike, number of grains per spike, grain yield per spike, biological yield per plant, and grain yield per plant; NW 3015 x Raj 4063 for number of spikelets per spike, number of grains per spike and 1000 - grain weight; K 209 x HD 2851 for plant height and number of grains per spike; UP 2614 x NW 3015 for 1000 - grain weight; UP 2614 x Raj 4063 for number of grains per spike; HUW 468 x PBW 520 for tillers per plant; K 209 x HD 2851 and HD 2851 x Raj 4063 for plant height. The crosses WH 789 x NW 3015, HUW 468 x UP 2614 and HS 448 x Raj 4063 emerged as good specific cross combinations for grain yield per plant. The parents WH 789, HUW 468, HD 2851 and Raj 4063 involved in these crosses were good general combiners for grain yield and one or two yield contributing traits

The information regarding three best performing parents, best general combiners, best performing hybrids (Table 3) revealed that parent with good per se performance were in general, good specific combinations for different traits. In many cases, it was observed that at least one good general combining parent was involved in heterotic hybrids having desirable sca effects. This suggests that information on gca effects of the parents should be considered along with sca effects and per se performance of hybrid for predicting the value of any hybrid.

Table 3. Best three parents, F_1s selected on the basis of their *per se* performance, GCA and SCA effects for various characters in wheat

Character	Per se performance		GCA	SCA
	Parents	F1		
Days to	HS 448	PBW 520 x Raj 4063	Raj 4063	HD 2881 x PBW 520
heading	HD 2851	WH 789 x HD 2851	HD 2851	PBW 520 x Raj 4063
	Raj 4063	HD 2851 x Raj 4063	WH 789	HUW 468 x UP 2614
Days to	HS 448	HS 448 x HD 2851	HS 448	HD 2881 x PBW 520
maturity	WH 789	HUW 468 x HD 2851	HD 2851	HUW 468 x Raj 4063
	HD 2851	K 209 x HD 2851	WH 789	NW 3015 x K 209
Plant height	HD 2851	HD 2851 x Raj 4063	HD 2851	HD 2851 x Raj 4063
	WH 789	UP 2614 x Raj 4063	WH 789	NW 3015 x K 209
	UP 2614	WH 789 x HD 2851	Raj 4063	UP 2614 x Raj 4063
Tillers	Raj 4063	NW 3015 x Raj 4063	Raj 4063	HS 448 x WH 789
per plant	HD 2851	HS 448 x Raj 4063	HD 2851	HS 448 x Raj 4063
	K 209	WH 789 x Raj 4063	WH 789	WH 789 x NW 3015
Flag leaf area	HD 2851	NW 3015 x Raj 4063	HD 2851	NW 3015 x Raj 4063
	NW 3015	UP 2614 x HD 2851	Raj 4063	HS 448 x WH 789
	Raj 4063	HS 448 x WH 789	UP 2614	UP 2614 x HD 2851
Spike length	NW 3015	HS 448 x HD 2851	HUW 468	HS 448 x HD 2851
	Raj 4063	HUW 468 x UP 2614	Raj 4063	K 209 x HD 2851
	UP 2614	HUW 468 x Raj 4063	UP 2614	HUW 468 x UP 2614
No. of grains	HUW 468	HUW 468 x UP 2614	HUW 468	HUW 468 x UP 2614
per spike	Raj 4063	K 209 x HD 2851	Raj 4063	K 209 x HD 2851
	WH 789	HD 2881 x HUW 468	-	HD 2881 x K 209
Grain yield	HUW 468	HUW 468 x UP 2614	Raj 4063	HUW 468 x UP 2614
per spike	WH789	HS 448 x Raj 4063	HUW 468	HD 2881 x K 209
	Raj 4063	HUW 468 x Raj 4063	HD 2881	K 209 x HD 2851
1000- Grain weight	HD 2851	UP 2614 x Raj 4063	HD 2881	UP 2614 x Raj 4063
	HUW 468	HS 448 x Raj 4063	Raj 4063	HS 448 x Raj 4063
	HD 2881	WH 789 x HUW 468	WH 789	HD 2881 x UP 2614
Biological	Raj 4063	HS 448 x Raj 4063	Raj 4063	HS 448 x Raj 4063
yield per	WH 789	NW 3015 x Raj 4063	UP 2614	WH 789 x NW 3015
plant	NW 3015	WH 789 x NW 3015	WH 789	HS 448 x WH 789
Harvest	Raj 4063	HD 2851 x Raj 4063	Raj 4063	HS 448 x PBW 520
index	UP 2614	K 209 x Raj 4063	K 208	PBW 520 x HD 2851
	NW 3015	HUW 468 x Raj 4063	-	UP 2614 x NW 3015
Grain yield per plant	Raj 4063	HS 448 x Raj 4063	Raj 4063	WH 789 x NW 3015
	NW 3015	NW 3015 x Raj 4063	WH 789	HS 448 x Raj 4063
	WH 789	WH 789 x NW 3015	HD 2881	K 209 x HD 2851

It is desirable to search out parental lines with high gca effects and low sensitivity to environmental variation in a crop improvement programme with respect to combining ability effects. From the present study following broad inferences could be drawn.

(i) In general, the crosses showing desirable sca effect for seed yield per plant also had high sca effects for some of it's yield contributing characters viz., No. of tillers, No. of spikelets. No. of grains/ spike and biological yield/ plant.

(ii) Best performing parents were mostly good general combiners for majority of the characters.

(iii) The crosses exhibiting desirable sca effects did not always involve parents with high gca effects, thereby suggesting the importance of intrallelic interaction.

It is clear from above discussion, that on the basis of SCA effects and *per se* performance the crosses - WH 789 x NW 3015, HUW 468 x UP 2614 and HS 448 x Raj 4063 emerged as good specific cross combinations for grain yield per plant. An over all appraisal revealed that the cross HUW 468 x UP 2614 emerged as good specific cross combinations for grain yield per plant. These crosses were the results of good x good, poor x poor and good x poor general combiners. These crosses hold great promise in improving the grain yield in future breeding programme of bread wheat.

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